DE GRUYTER OPEN

DOI: 10.1515/sspjce-2018-0022

Recent climate change in Syria: Seasonal rainfall and climatology of Syria for 1991-2009

Ibrahim Alkhalaf, Tatiana Solakova, Martina Zelenakova, Ibrahim Gargar

Technical University of Košice, Slovakia
Civil Engineering Faculty, Institute of Environmental Engineering
e-mail: alkhalaf.ibrahim@gmail.com, tanik@post.sk, martina.zelenakova@tuke.sk, ebrahimkhalifa1@gmail.com

Abstract

Trend analysis is one of the most commonly used tools for detecting changes in climatic and hydrologic time series. Attempts are devoted to the study of seasonal climatology in Syria, including information on the level of rainfall at various climatic stations in Syria for the period 1991-2009. Wet (from October to May) and dry (June to September) seasonal precipitation are obtained from surface observations. There are numbers of statistical tests that exist to assess the significance of trends in time series. However, the existence of positive autocorrelation in the data increases the probability of detecting trends when actually none exist, and vice versa. Most of the recent studies about climate change suggest that the behavior of some of the climatological variables has already changed and will continue to change towards increasing or decreasing magnitudes and frequencies, depending on the type of variable. Increased rainfall and following floods are expected in some regions while other regions will experience smaller rainfall and longer droughts, meaning water scarcity.

Key words: Syria, statistical methods, climatic station, rainfall, precipitations, climate change

1 Introduction

Climate change is viewed as liable to increase runoff in the higher latitude regions because of increased precipitation on the other hand flood frequencies are expected to change also in some locations and the severity of drought events could increase as a result of those changes in both precipitation and evaporation. In all these considerations ‘the issue’ then becomes the effect of global warming and its impacts on the environment and water resources in particular. Precipitation is one of the most important variables for climate and hydro-meteorology. Changes in precipitation pattern may lead to floods, droughts, loss of biodiversity and agricultural productivity. Subsequently, the spatial and temporal trends of precipitation results are important for climate analyst and water resources planner. Precipitation has changed worldwide during the last decades mainly due to climate variability. Climate change studies have demonstrated that the land-surface precipitation shows an increase of 0.5–1% per decade

in most of the Northern Hemisphere mid and high latitudes, and annual average of regional precipitation increased 7–12% for the areas in 30–85° N and by about 2% for the areas 0°–55° S over the 20th century [1].
Many researchers have given a great deal of attention to the potential impacts of climatic change and variability in several fields at international level. Only some of them have investigated the rainfall variability in Syria. For instance, Endo et al. [2] investigated trends in extreme precipitation using almost the entire network of stations in Southeast Asia. Almazroui et al. [3 & 4] gave insight into the recent, past and present climate as well as climate change in the Arabian Peninsula, in particular over Syria. The Middle East countries, including those on the Arabian Peninsula, are characterized by large variations in their climatic conditions, and these variations can be significant within a single country [5 & 6]. Some studies in Iran have examined the changes in meteorological variables. In contrary their results showed that there was no statistically significant climate variability or only slightly decreasing trend in annual precipitation in Iran [7 & 8]. Almost no study is devoted to rainfalls trend or climate variability and its impact to water resources (to the best authors' knowledge) in Syria.
Rainfall is a critical meteorological parameter and needs to be measured and evaluated accurately; many applications of rainfall data can be studied in depth through knowledge of the actual distribution of rainfall. Additionally, the amount of rainfall received over an area is an important factor in assessing the amount of water available to meet the various demands of agriculture, industry, and other human activities [9]. This paper investigates rainfall trends over all Syria. Data for evaluation were obtained from Aleppo University in Syria with collaboration of Ministry of Agriculture and Agrarian Reform and Meteorological Center in Syria. The evaluated period is from 1991 to 2009.

2 Study area and methodology

Syria, with its area 185,180 km² is situated in the Middle East (Figure 1), bordering the Mediterranean Sea between Turkey and Lebanon. Terrain is narrow coastal plain with a twofold mountain belt in the west; large, semiarid and desert plateau to the east. Climate is mostly deserted; it has hot, dry, sunny summers (from June to August) and mild, rainy winters (December to February) along coast.

It is important to evaluate how climate has varied and changed in the past. The monthly mean historical rainfall and temperature data can be mapped to show the baseline climate and seasonality by month, for specific years, and for rainfall and temperature.

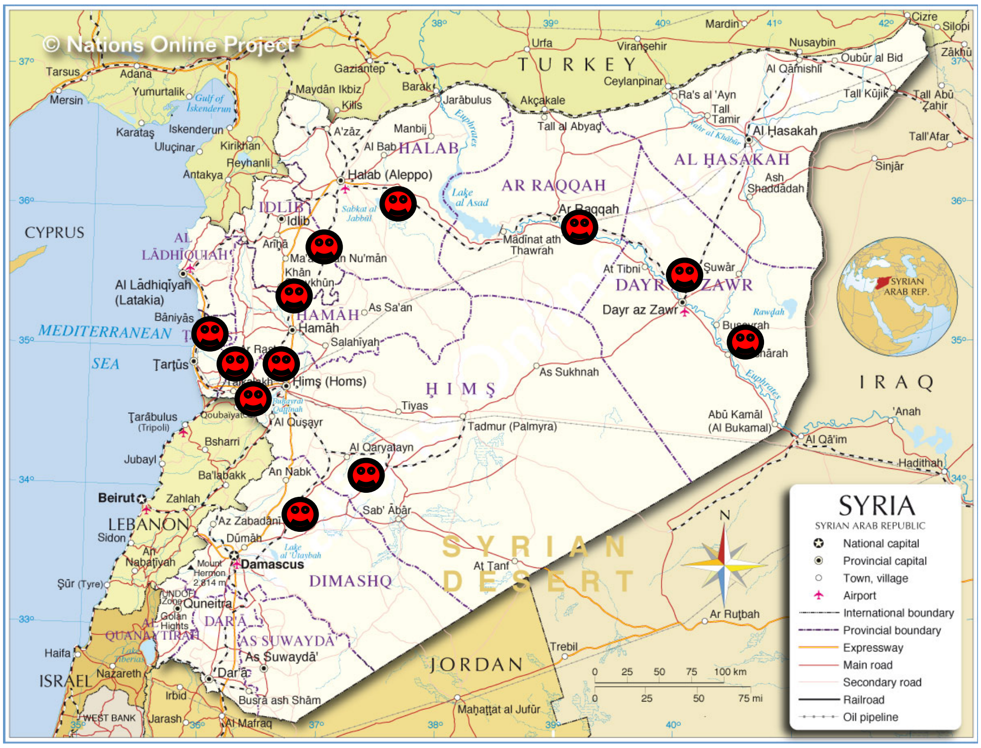


Figure 1: Study area with marked climatic stations

The climate of the study area significantly affects deductions under which it is divided into two divisions:

- Mediterranean climate in the coastal zone and adjacent areas
- Dry climate in the inland.

The Mediterranean climate is characterized by hot, dry summers and cold winter rains with the presence of the two transitional periods which are fall and spring.

Dry climate is characterized by a minimum of cold precipitation in winter, when temperatures drop below zero, and vice versa very hot summers, and contributing in mountain areas with highlands temperatures are mild and summers on the basis of the altitude.

Rainfall is usually from September to May each year, on the western side of the mountains are observed occasional snowfall.

Unevenness in precipitation between the coasts with inland areas can be distinguished in three areas:

- Areas on the high seas, torrential rains of up to cumulated 1200 mm/year
- Inland areas adjacent to coastal areas where the rainfall decreases to around 250 mm / year and rises up to 550 mm / year in the north and north-east
- Desert regions, representing about 60% of the country where the of rainfall rate is not more than 150 mm / year.

The region of Syria is faced with the challenges posed by growing populations, lack of international agreements on transboundary water resources, poor water management, with growing risks of climate change.

Table 1: Localization of gauging stations in Syria

Station	Latitude	Longitude	Altitude
Arihah	35°48´50´´	36°36´27´´	597
Khan Shaykhun	35°26´31´´	36°39´26´´	378
Al Quaryatayn	34°13´51´´	37°14´18´´	750
Tal Kalakh	34°40´06´´	36°15´27´´	290
Al Nabk	34°00´49´´	36°44´00´´	1279
Al Busayrah	35°09´17´´	40°25´43´´	200
Al Tebni	35°36´17´´	39°49´09´´	234
Ebla	35°56´08´´	36°37´23´´	424
Al Qadmus	35°06´03´´	36°09´40´´	926
Baniyas	35°11´08´´	35°57´11´´	33
Ar Reqqah	35°57´36´´	38°59´52´´	248
Ain Issa	36°23´03´´	38°52´03´´	344

The paper is devoted to rainfall analyses of the selected rain gauge stations. The trend analysis in the stations was done based on Mann Kendall nonparametric test. In the Mann Kendall trend test, the null hypothesis H0 of the trend test is that there is no trend and the data are random and independent; alternate hypothesis H1 is that a trend is present in the time series. If number of data $n \geq 10$, the test statistic can be approximated using normal distribution and the normalized test statistic Z can then be computed [10 & 11]. In a two-tailed test, $|Z| > Z_{1-\alpha/2}$ indicates that the null hypothesis has been rejected with α being the significance level of the test. For this study, significance levels of 0.05 were utilized. The non-parametric estimate of the trend magnitude of the slope, β of linear trend, was taken to be the Theil Sen's slope as proposed by Theil [12] and Sen [13]. Theil Sen's slope (β) is calculated as the median of all possible slopes.

3 Rainfall analyses

Rainfall is an important parameter for any vulnerability assessment in a changing climate and its analysis depends on the variations in its mean, maximum and minimum values. Therefore, the details of the seasonal mean, maximum and minimum rainfalls are taken into consideration for this discussion. Analyzing the mean rainfall is important for any region but the assessment of maximum and minimum rainfall in particular is necessary for many application-oriented tasks, such as the study of extremes and agriculture.

Figure 2 and Figure 3 data showed that the distribution of annual rainfall over the Syria from data obtained from 74 climatic stations varies greatly from place to place and from time to time. The surface information from observation in climatic stations and the corresponding rainfall amounts (mm) over Syria during the period 1991–2009 is under mentioned. Wet (from October to May) and dry (June to September) seasons are various colored marked.

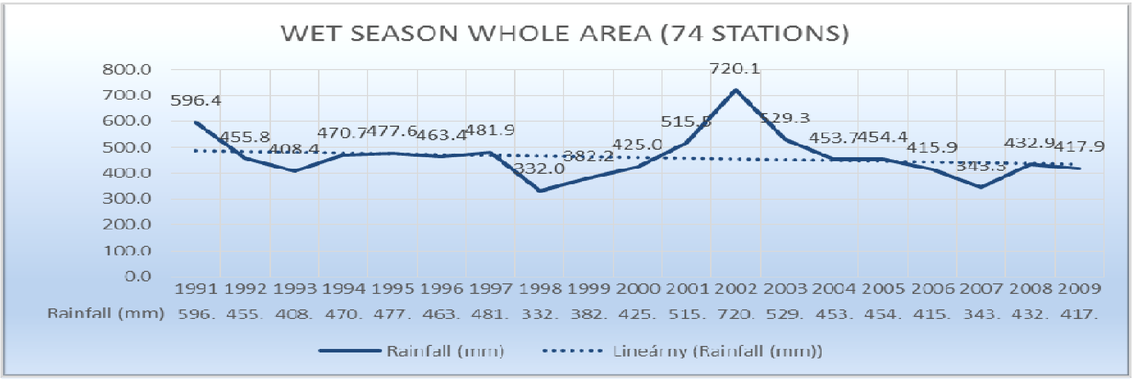


Figure 2: Graphical representation of the wet season rainfall in Syria averaged over the period 1991-2009 obtained from 74 climatic stations

As we approached from the chart of the wet season data of 74 climatic stations strategically located all over Syria, the highest rate of rainfall was recorded in 2002 (720.1 mm) and the lowest in 1998 (332.0 mm). The curve has a decreasing trend.

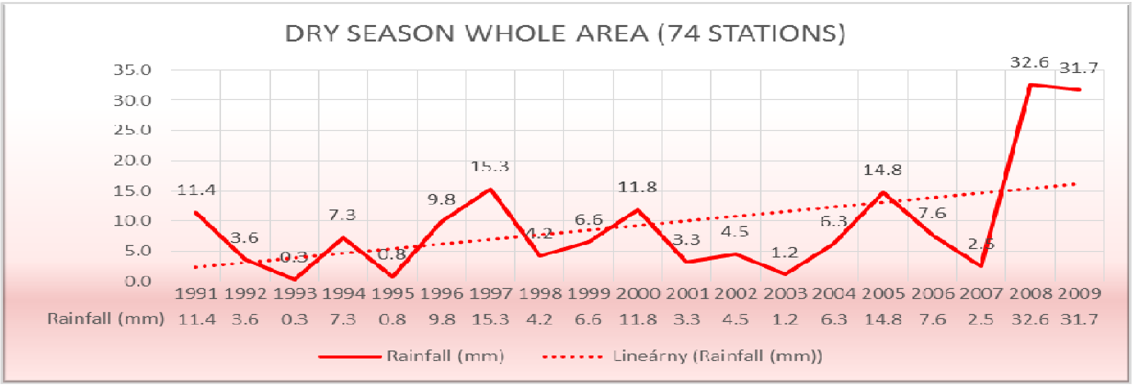
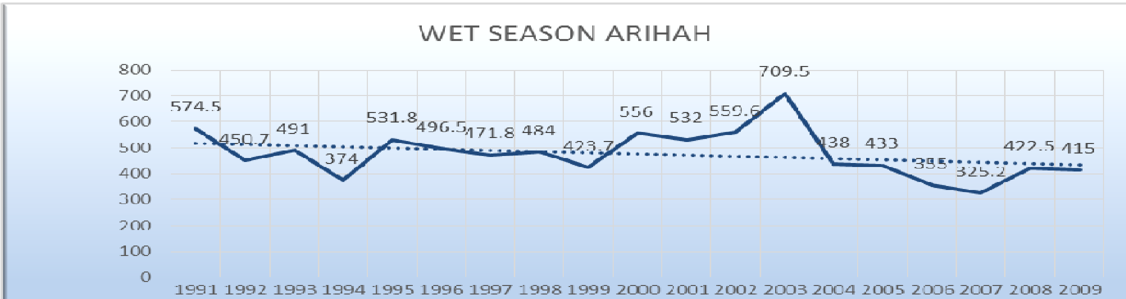


Figure 3: Graphical representation of the dry season rainfall in Syria averaged over the period 1991-2009 obtained from 74 climatic stations

As we approached from the Figure 3 that depicts dry season data of 74 climatic stations strategically located all over Syria, the highest rate of rainfall was recorded in 2008 (32.6 mm) and the lowest in 1993 (0.3 mm). The curve has an increasing trend.

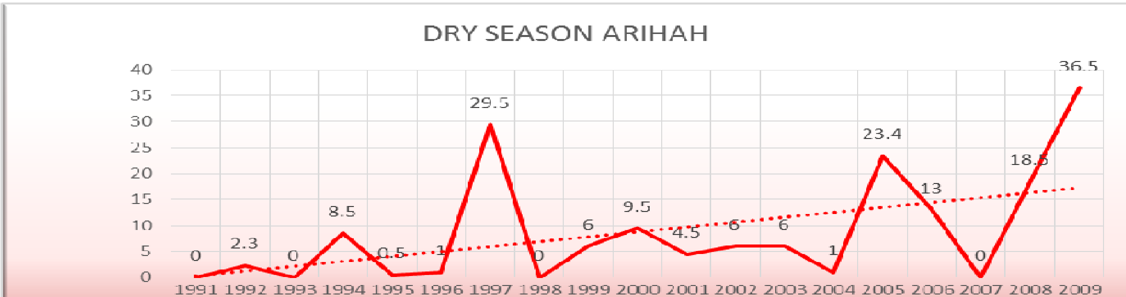
Middle Eastern countries, including those in the Arabian Peninsula, are characterized by large differences in their climatic conditions and these changes may be significant within a country. From north to south in Syria are major changes in climatic conditions. In terms of rainfall the most of the southwest area of the rest of the country is dry. Any increase in temperature is accompanied by a decrease in rainfall. Linder (2006) states in the field of advanced changes in rainfall with a tendency to damp places that will become even wetter and the dry and arid, which will become even a dryer areas. A precondition of these changes may become floods caused by heavy rains and drought caused by deficiency of rain. In the following we assessed rainfall in twelve climate stations (from 74).



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Rainfall (mm)	575	451	491	374	532	497	472	484	424	556	532	560	710	438	433	355	325	423	415

Figure 4: Graphical representation of the wet season rainfall in Arihah averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 4 that depicts wet season data of climatic station situated in Arihah (Syria), the highest rate of rainfall was recorded in 2003 (709.5 mm) and the lowest in 2007 (325.2 mm). The curve has decreasing trend.



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Rainfall (mm)	0	2.3	0	8.5	0.5	1	29.5	0	6	9.5	4.5	6	6	1	23.4	13	0	18.5	36.5

Figure 5: Graphical representation of the dry season rainfall in Arihah averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 5 that depicts dry season data of climatic station situated in Arihah (Syria), the highest rate of rainfall was recorded in 200 (36.5 mm) and the lowest in 1991, 1993, 1998 (0 mm). The curve has an increasing trend.

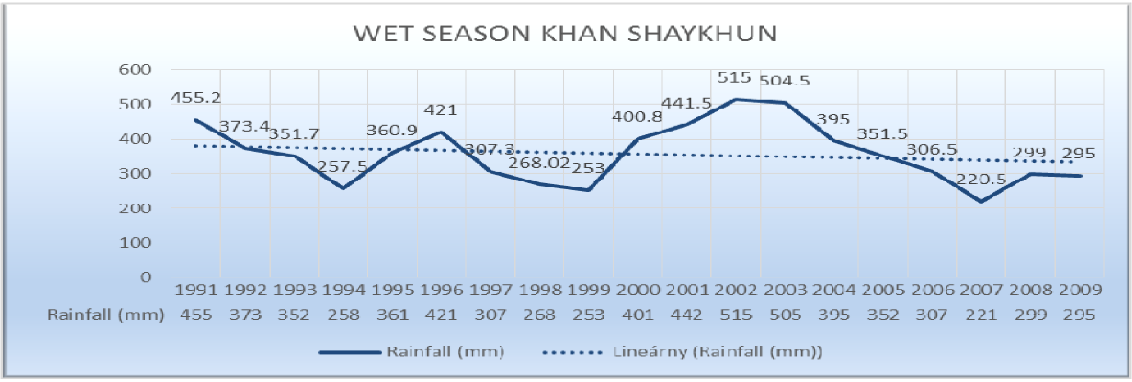


Figure 6: Graphical representation of the wet season rainfall in Khan Shaykhun averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 6 that depicts wet season data of climatic station situated in Khan Shaykhun (Syria), the highest rate of rainfall was recorded in 2002 (515 mm) and the lowest in 2007 (220.5 mm). The curve has decreasing trend.

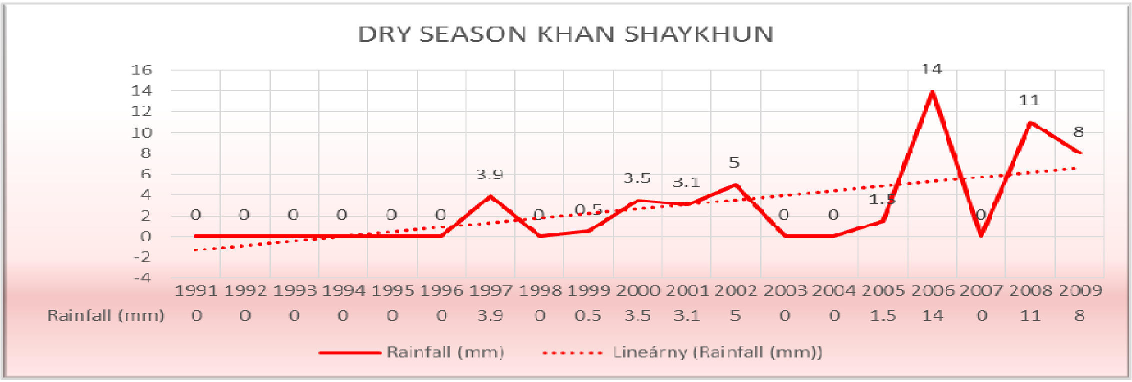


Figure 7: Graphical representation of the dry season rainfall in Khan Shaykhun averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 7 that depicts dry season data of climatic station situated in Khan Shaykhun (Syria), the highest rate of rainfall was recorded in 2006 (14 mm) and the lowest in 1991-1996 (0 mm). The curve has an increasing trend.

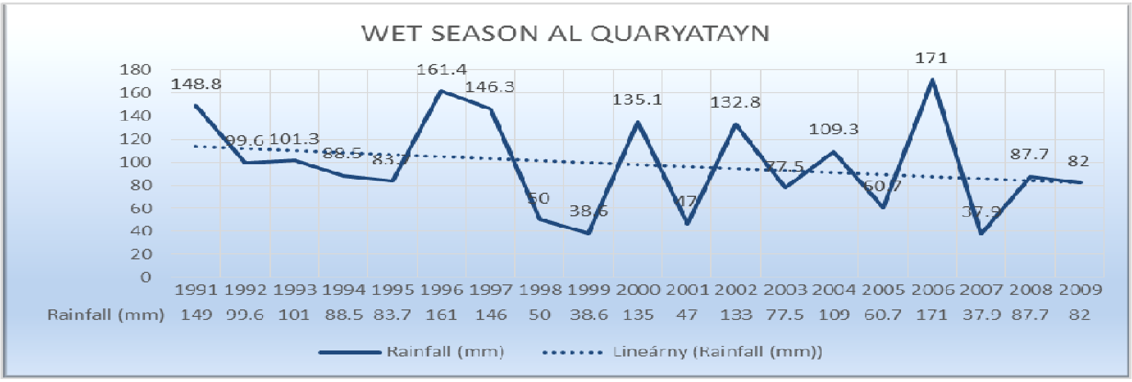


Figure 8: Graphical representation of the wet season rainfall in Al Quaryatayn averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 8 that depicts wet season data of climatic station situated in Al Quaryatayn (Syria), the highest rate of rainfall was recorded in 2006 (171 mm) and the lowest in 2007 (37.9 mm). The curve has decreasing trend.

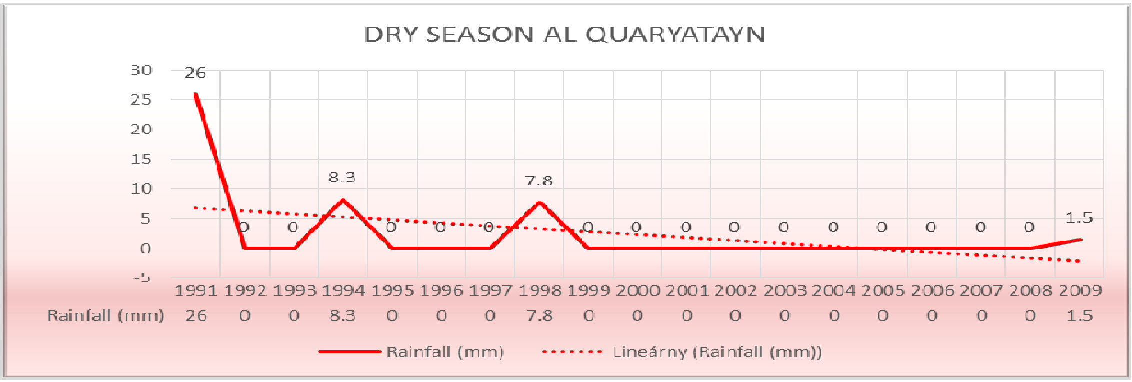


Figure 9: Graphical representation of the dry season rainfall in Al Quaryatayn averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 9 that depicts dry season data of climatic station situated in Al Quaryatayn (Syria), the highest rate of rainfall was recorded in 1991 (26 mm) and the lowest in 1999-2008 (0 mm). The curve has decreasing trend.

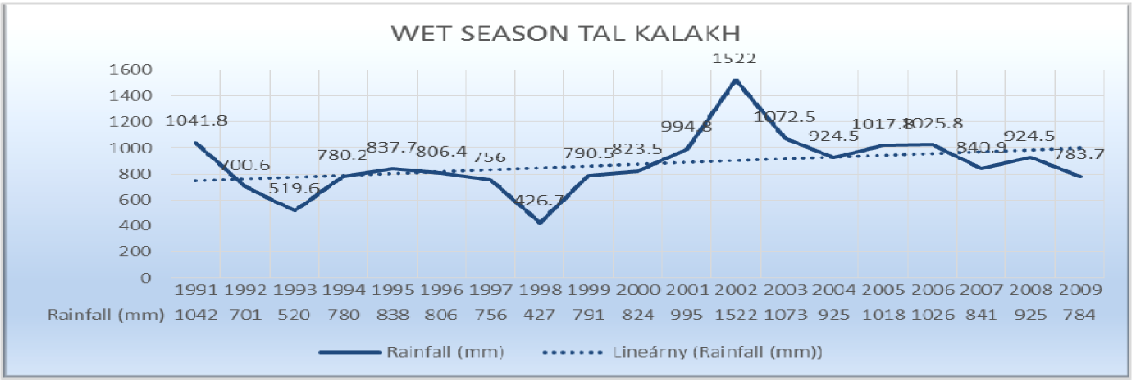


Figure 10: Graphical representation of the wet season rainfall in Tal Kalakh averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 10 that depicts wet season data of climatic station situated in Tal Kalakh (Syria), the highest rate of rainfall was recorded in 2002 (1522 mm) and the lowest in 1998 (42672 mm). The curve has an increasing trend.

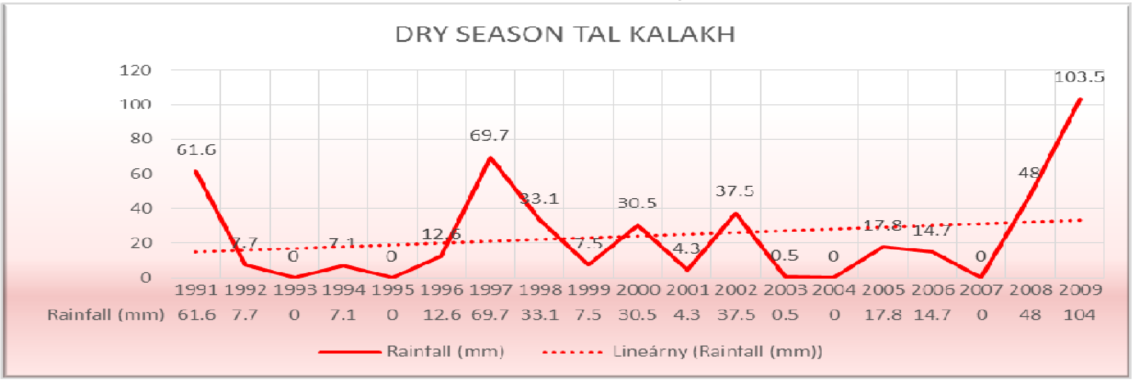


Figure 11: Graphical representation of the dry season rainfall in Tal Kalakh averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 11 that depicts dry season data of climatic station situated in Tal Kalakh (Syria), the highest rate of rainfall was recorded in 2009 (103.5 mm) and the lowest in 1993, 1995, 2004 (0 mm). The curve has an increasing trend.

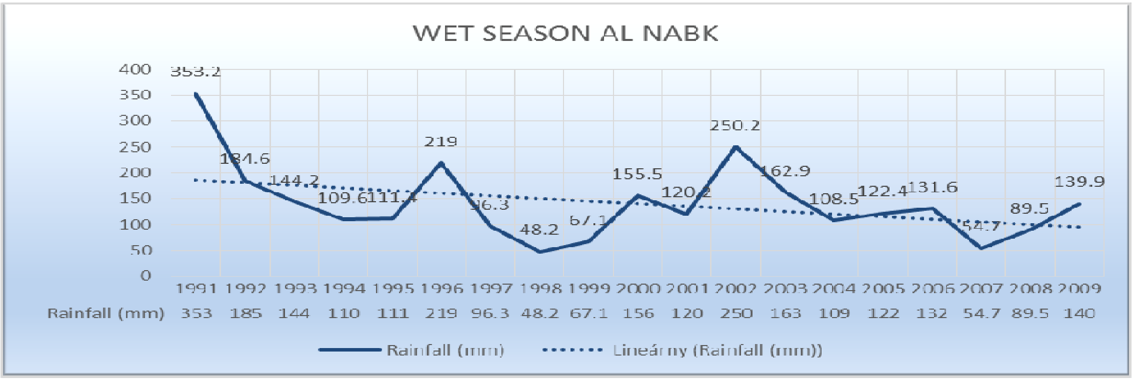


Figure 12: Graphical representation of the wet season rainfall in Al Nabk averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 12 that depicts wet season data of climatic station situated in Al Nabk (Syria), the highest rate of rainfall was recorded in 1991 (353.2 mm) and the lowest in 1998 (48.2 mm). The curve has decreasing trend.

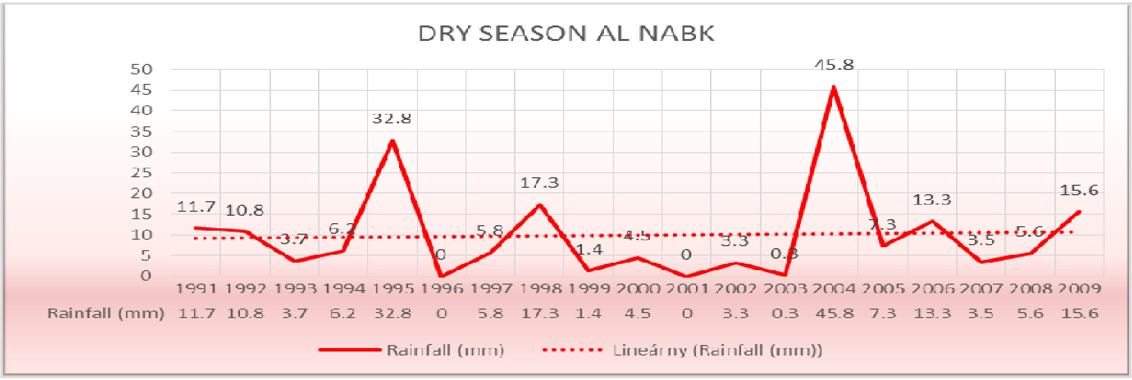


Figure 13: Graphical representation of the dry season rainfall in Al Nabk averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 13 that depicts dry season data of climatic station situated in Al Nabk (Syria), the highest rate of rainfall was recorded in 2004 (45.8 mm) and the lowest in 1996 (0 mm). The curve has no significant trend.

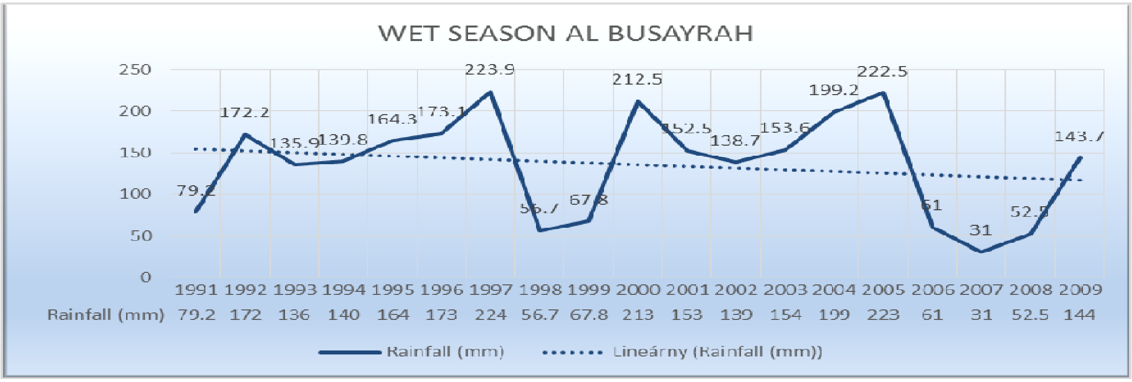


Figure 14: Graphical representation of the wet season rainfall in Al Busayrah averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 14 that depicts wet season data of climatic station situated in Al Busayrah (Syria), the highest rate of rainfall was recorded in 1997 (223.9 mm) and the lowest in 1998 (56.7 mm). The curve has decreasing trend.

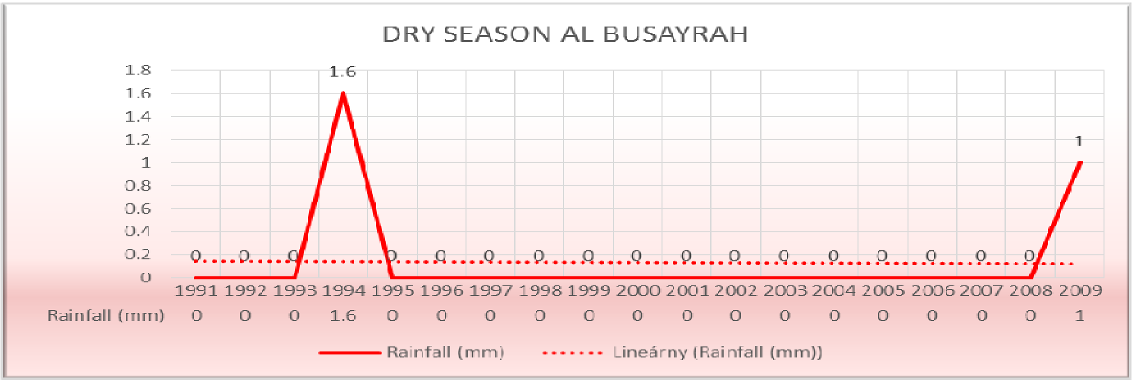


Figure 15: Graphical representation of the dry season rainfall in Al Busayrah averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 15 that depicts dry season data of climatic station situated in Al Busayrah (Syria), the highest rate of rainfall was recorded in 1994 (1.6 mm) and the lowest in 1995-2008 (0 mm). The curve has no significant trend.

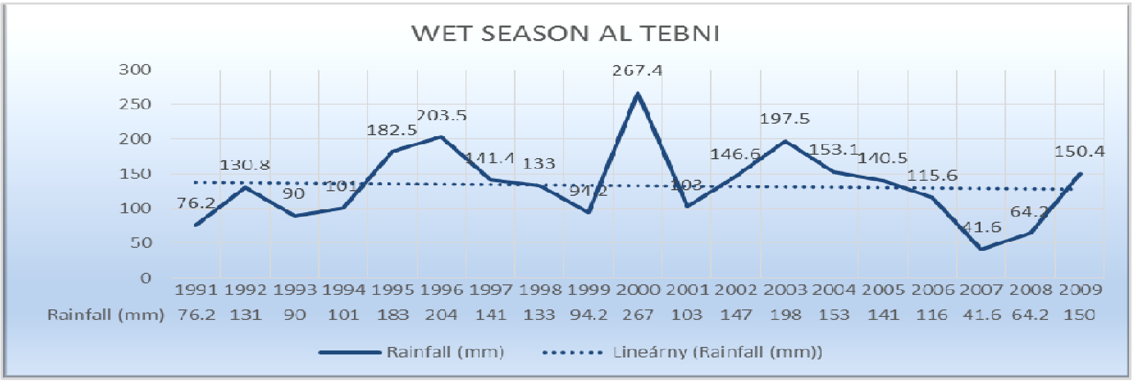


Figure 16: Graphical representation of the wet season rainfall in Al Tebni averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 16 that depicts wet season data of climatic station situated in Al Tebni (Syria), the highest rate of rainfall was recorded in 2000 (267.4 mm) and the lowest in 2007 (41.6 mm). The curve has no significant trend.

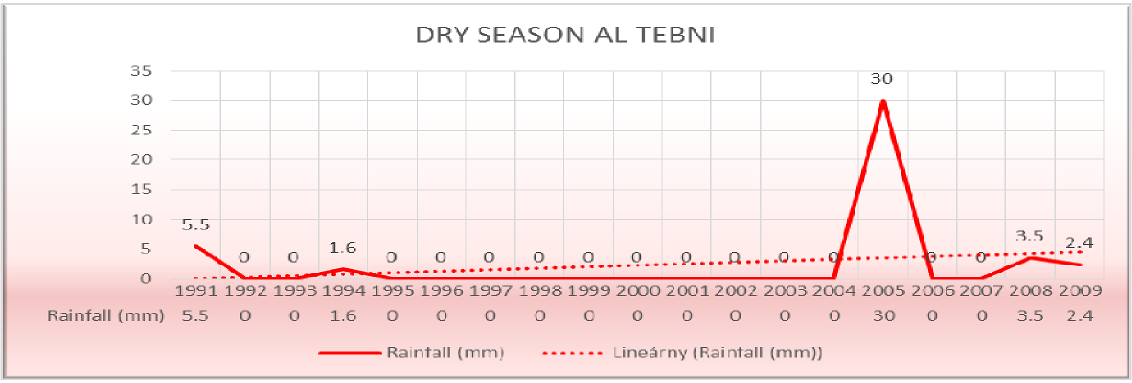


Figure 17: Graphical representation of the dry season rainfall in Al Tebni averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 17 that depicts dry season data of climatic station situated in Al Tebni (Syria), the highest rate of rainfall was recorded in 2005 (30 mm) and the lowest in 1995-2003 (0 mm). The curve has an increasing trend.

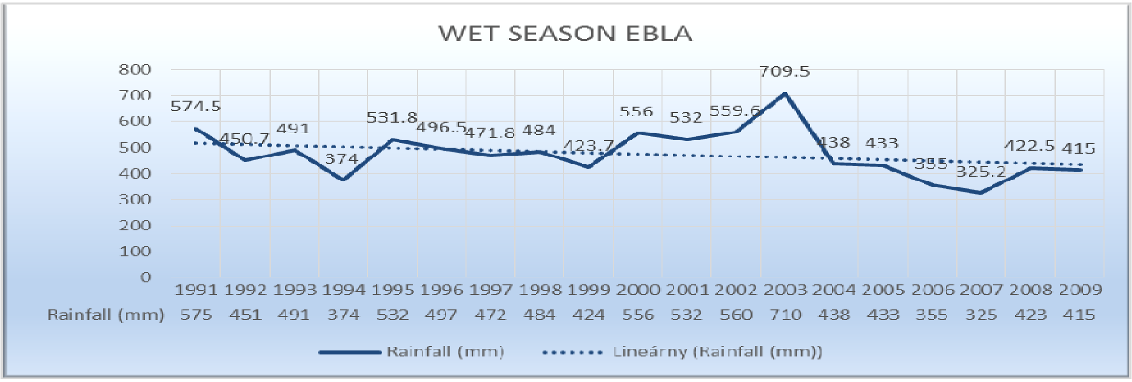


Figure 18: Graphical representation of the wet season rainfall in Ebla averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 18 that depicts wet season data of climatic station situated in Ebla (Syria), the highest rate of rainfall was recorded in 2003 (709.5 mm) and the lowest in 2007 (325.2 mm). The curve has decreasing trend.

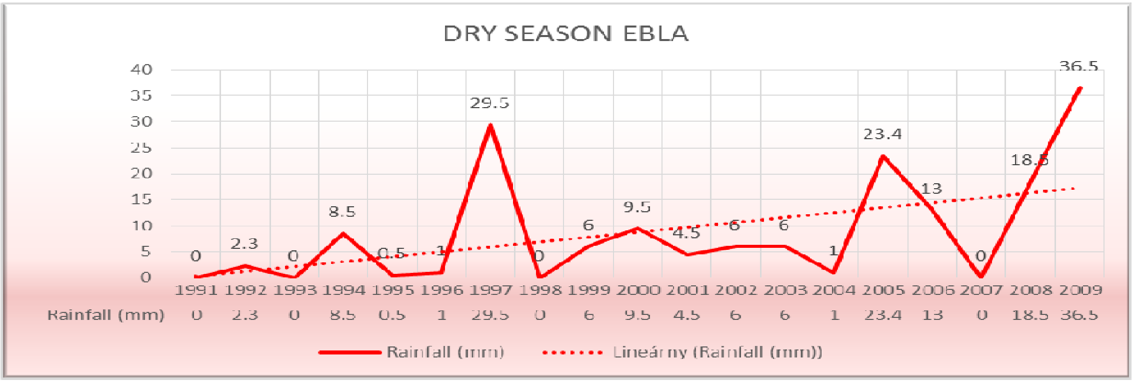


Figure 19: Graphical representation of the dry season rainfall in Ebla averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 19 that depicts dry season data of climatic station situated in Ebla (Syria), the highest rate of rainfall was recorded in 2009 (36.5 mm) and the lowest in 1991, 1993, 1998, 2007 (0 mm). The curve has an increasing trend.

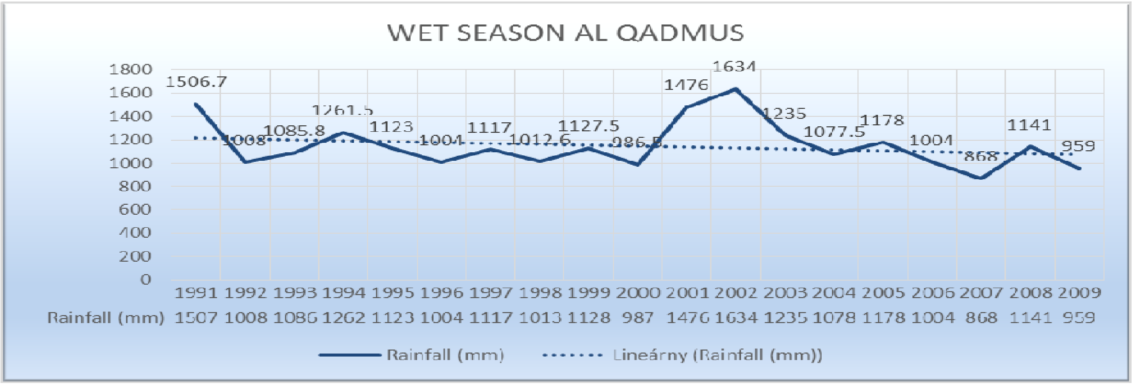


Figure 20: Graphical representation of the wet season rainfall in Al Qadmus averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 20 that depicts wet season data of climatic station situated in Al Qadmus (Syria), the highest rate of rainfall was recorded in 2002 (1634 mm) and the lowest in 2007 (868 mm). The curve has decreasing trend.

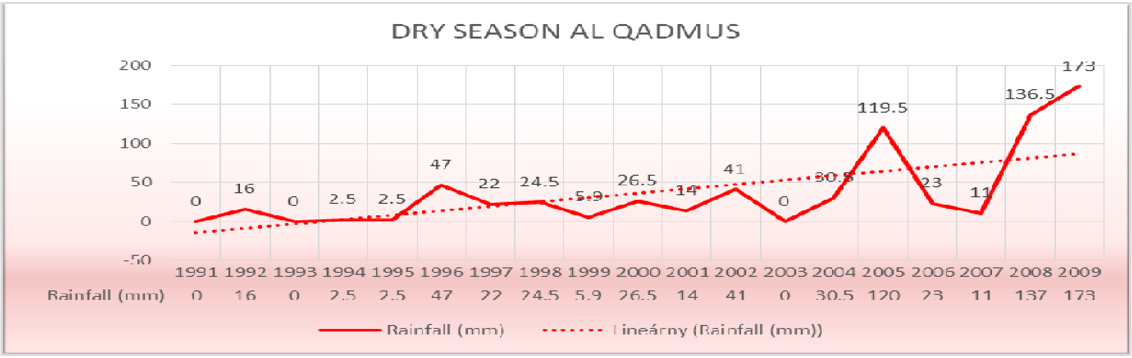


Figure 21: Graphical representation of the dry season rainfall in Al Qadmus averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 21 that depicts dry season data of climatic station situated in Al Qadmus (Syria), the highest rate of rainfall was recorded in 2009 (173 mm) and the lowest in 1991, 1993, 2003 (0 mm). The curve has an increasing trend.

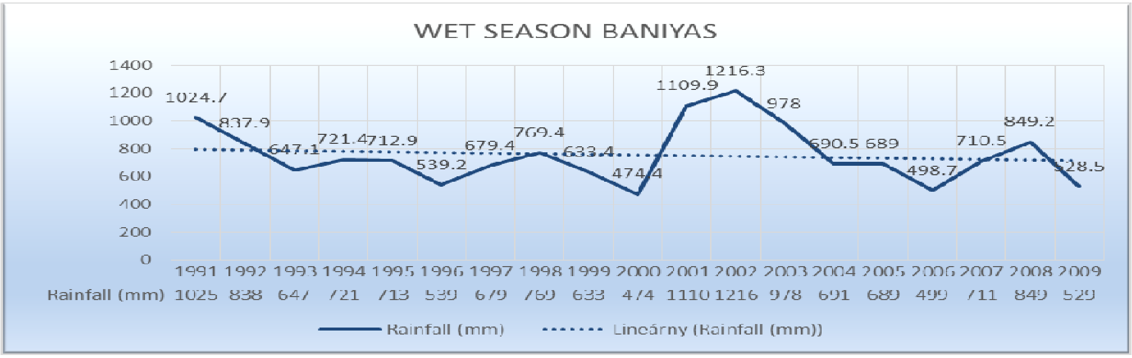


Figure 22: Graphical representation of the wet season rainfall in Baniyas averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 22 that depicts wet season data of climatic station situated in Baniyas (Syria), the highest rate of rainfall was recorded in 2002 (1216.3 mm) and the lowest in 2000 (474.4 mm). The curve has decreasing trend.

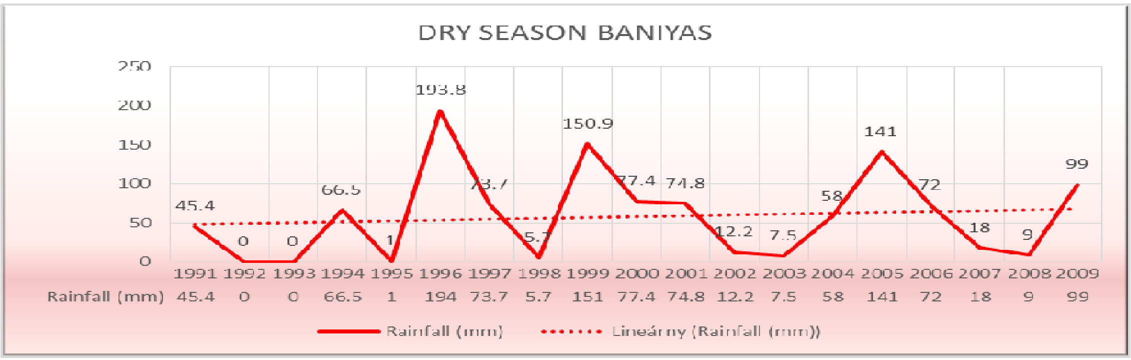


Figure 23: Graphical representation of the dry season rainfall in Baniyas averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 23 that depicts dry season data of climatic station situated in Baniyas (Syria), the highest rate of rainfall was recorded in 1996 (193.8 mm) and the lowest in 1992-1993 (0 mm). The curve has an increasing trend.

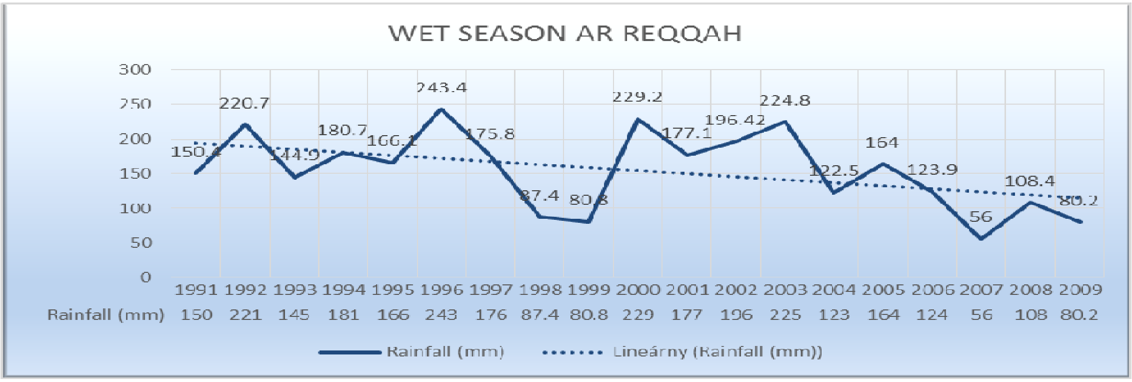


Figure 24: Graphical representation of the wet season rainfall in Ar Reqqah averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 24 that depicts wet season data of climatic station situated in Ar Reqqah (Syria), the highest rate of rainfall was recorded in 1996 (243.4 mm) and the lowest in 2007 (56 mm). The curve has decreasing trend.

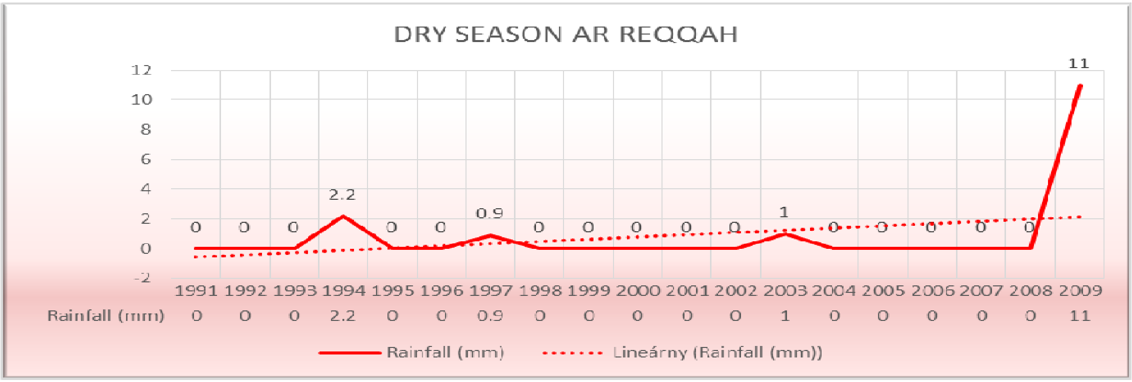


Figure 25: Graphical representation of the dry season rainfall in Ar Reqqah averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 25 that depicts dry season data of climatic station situated in Ar Reqqah (Syria), the highest rate of rainfall was recorded in 2009 (11 mm) and the lowest in 1991-1993,1995,1996, 1998-2002, 2004-2008 (0 mm). The curve has an increasing trend.

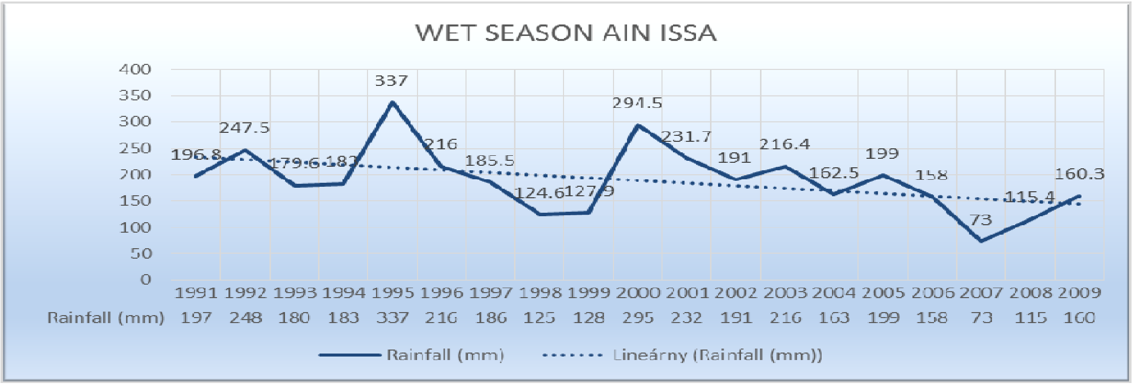


Figure 26: Graphical representation of the wet season rainfall in Ain Issa averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 26 that depicts wet season data of climatic station situated in Ain Issa (Syria), the highest rate of rainfall was recorded in 1995 (337 mm) and the lowest in 2007 (73 mm). The curve has decreasing trend.

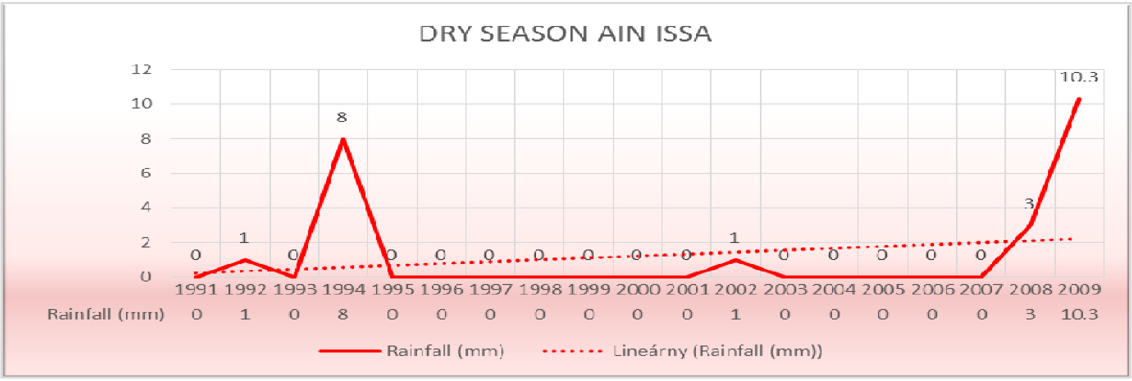


Figure 27: Graphical representation of the dry season rainfall in Ain Issa averaged over the period 1991-2009 obtained from climatic station

As we approached from Figure 27 that depicts dry season data of climatic station situated in Ain Issa (Syria), the highest rate of rainfall was recorded in 2009 (10.3 mm) and the lowest in 1996-2001 (0 mm). The curve has an increasing trend.

4 Results

Current monitoring of rainfall collision in the study areas confirms the topicality of the issue of drainaging of rain water and the necessity of the policies the negative effects linked to rainfall, such as floods and lack of drinking water in Syria. The aim of addressing these negative effects is the prevention of adverse hydrological events in dealing with floods (floods in Syria, prolonged droughts), resulting in a temporary detention system design and economic usage of rainwater in the assessed area, especially in the dry seasons.

Results of rainfall analysis – annual trends and seasonal trends are presented in Table 2. Monthly data series for the 21 years period, from 1991-2009, were considered for trend detection.

Table 2: Annual and seasonal trends of rainfall in gauging stations in Syria

Station	Period IX-V	Period IX-XI	Period XII-II	Period III-V
Arihah	-0.0135	0.1460	0.0759	**-0.3556**
Khan Shaykhun	-0.0110	0.1552	-0.0520	**-0.2973**
Al Quaryatayn	-0.0041	0.0000	0.0020	**-0.0100**
Tal Kalakh	0.0709	**0.7228**	1.0171	-0.1481
Al Nabk	-0.0205	**-0.1667**	0.0000	-0.0500
Al Busayrah	-0.0089	0.0000	-0.1600	**-0.0950**
Al Tebni	0.0000	**0.0029**	-0.0385	-0.0780
Ebla	-0.0135	0.1460	0.0759	**-0.3556**
Al Qadmus	0.0116	**0.8182**	-0.2553	-0.7353
Baniyas	0.0397	**0.4545**	-0.3263	-0.2192
Ar Reqqah	-0.0163	0.0000	**-0.2613**	-0.1120
Ain Issa	-0.0185	0.0000	**-0.3143**	-0.0308

As it is obvious from Table 2 there are significant trends in rainfall data series that were proved in annual statistical analysis.

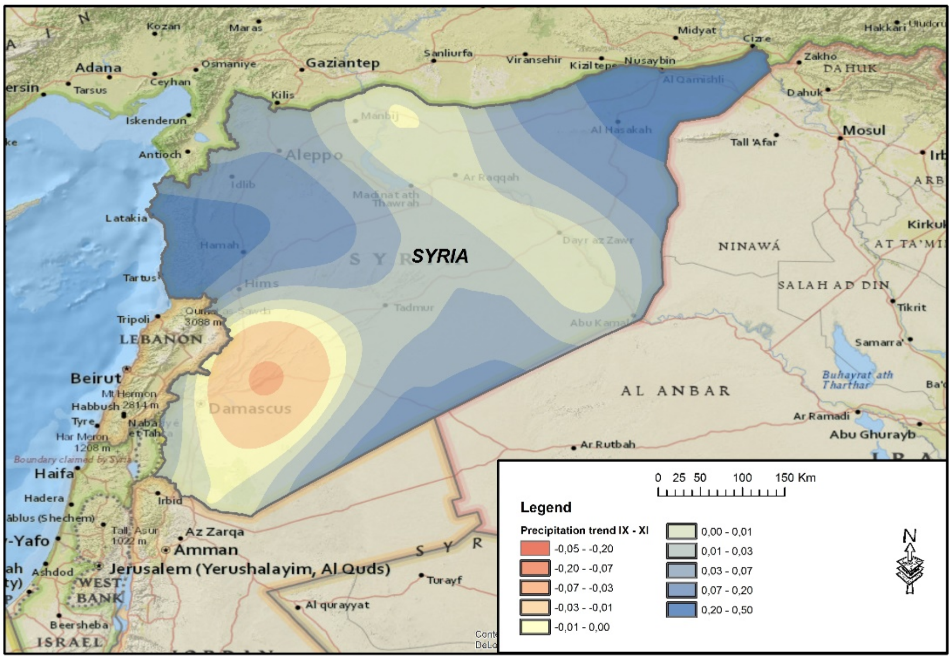


Figure 28: Spatial distribution of rainfall trends from September until November

The period from September until November proved increasing trends in rainfall, the significant increasing trends were proved in stations: Tal Kalakh, Al Tebni, Al Qadmus and Baniyas, situated in the southwestern part of the Syria at Mediterranean seaside (Figure 10-11, 16-17, 20-23). The significant decreasing trend was proved only in station Al Nabk. The winter season – period from December to February showed mostly decreasing trends in rainfall in the evaluated 21 years period. The significant negative trends in rainfall time series were proved in stations Ar Reqqah and Ain Issa (Figure 24-27). During the period from March to May in all stations were detected decreasing trends and exactly the gauging stations Arihah, Ebla, Khan Shaykhun, Al Quaryatayn, Al Busayrah (Figure 4-9, 14-15, 18-19) proved significant decreasing trends in rainfall. All these stations (except Al Quaryatayn) are situated in the northwestern part of the country. Figure 28 presents spatial distribution of rainfall trends.
The next trend analysis was devoted to trend investigation in rainfall data series for separate months during the year in gauging stations in Syria. The analysis was done for months from September to May as during June, July and August there are almost no rainfall in Syria.

Table 3: Monthly trends of rainfall in gauging stations in Syria

Station	Month								
	IX	X	XI	XII	I	II	III	IV	V
Arihah	**0.5455**	0.1667	-0.2500	1.0000	0.1667	0.4000	-2.2133	-0.1667	-0.5000
Khan Shaykhun	**0.0100**	0.6267	0.1000	0.8333	-0.1800	-0.9545	-1.0357	0.6222	-0.5403
Al Nabk	0.0895	**-1.6000**	-0.5500	0.5786	-0.7636	-0.2333	-0.3714	0.1250	-0.1857
Al Quaryatayn	0.0000	0.1500	-0.1500	0.6667	0.3000	-0.6611	**-0.6000**	-0.1000	0.0000
Tal Kalakh	0.3333	0.3273	2.8250	2.0500	3.3750	2.9286	-0.9500	**3.1625**	**-0.7571**
Al Nabk	0.0895	**-1.6000**	-0.5500	0.5786	-0.7636	-0.2333	-0.3714	0.1250	-0.1857
Al Busayrah	0.0000	**0.2533**	0.0778	-0.5375	-0.5600	-0.5000	-0.1417	-0.2833	-0.1000
Al Tebni	**0.0120**	**0.3455**	0.0000	-0.2600	0.0333	-0.2833	-0.2000	-0.0800	0.0000
Ebla	**0.5455**	0.1667	-0.2500	1.0000	0.1667	0.4000	-2.2133	-0.1667	-0.5000
Al Qadmus	**0.8429**	2.1429	1.4000	-2.7727	0.5000	0.6154	-2.1000	1.9167	-1.0240
Baniyas	0.9500	**2.3000**	0.5125	-1.6667	1.0000	-2.1000	-1.8125	0.6333	-0.1667
Ar Reqqah	0.0000	0.1667	-0.5800	0.0300	**-1.2667**	-0.8600	-0.1938	-0.3667	-0.0286
Ain Issa	0.0000	-0.0833	-0.6667	-0.4000	-1.3333	-0.8769	0.0714	-0.0909	0.0000

Regarding trend analysis of monthly rainfall data (Table 3) is proved clear decreasing trend in rainfall in May and clear increasing trend in rainfall in September. It proves increasing extremity in rainfall events in Syria.

5 Conclusion

Nowadays rainwater from most built-up or otherwise surface of closed areas is not receiving back in natural way into the natural water cycle. These can cause gradual, long term changes of soil structure and water regimes, leading to a reduction of the natural regeneration of local ground water and affecting the chemical and biological conditions of the terrain below. Also harmless diversion of surface runoff, especially those in extreme strong precipitation events requires considerable technical and financial expenditure for the design, construction and operation of sewerage networks and wastewater treatment plants.

The rainfall analyses in the Syria was investigated based on 74 climatic stations with daily precipitation records from 1992–2010. Nonparametric Mann Kendall test and Theil Sen analysis methods were applied for significant trend detection and magnitude of trends, respectively. Negative trends of annual rainfall were found in the analysed climatic stations, denoting a decrease in rainfall in almost all climatic stations, especially in the north (mountainous) and western (coastline) parts of the country.

References

[1] Polčák, N. (2007). Basics of climate science for geographers. University textbooks. Banská Bystrica: Faculty of Natural Sciences of Matej Bel University. 116 s.

[2] Endo, N., Matsumoto, J. & Lwin, T. (2009). Trends in precipitation extremes over Southeast Asia, *SOLA*. *5*, 168–171.

[3] Almazroui, M., Islam, M.N., Athar, H., Jones, P.D., & Rahman, M.A. (2012). Recent climate change in the Arabian Peninsula: Annual rainfall and temperature analysis of Saudi Arabia for 1978-2009. *Int. J. Climatol.* DOI: 10.1002/joc.3446.

[4] Almazouri, M. (2011). Calibration of TRMM rainfall climatology over Saudi Arabia during 1998-2009. *Atmos. Res. 99*, 400-414.

[5] Ragab, R. & Prudhomme, C. (2000). Climate change and water resources management in the southern Mediterranean and Middle East countries. *The Second World Water Forum*, 17-22.

[6] Ragab, R. & Prudhomme C. (2002). Climate Change and Water Resources Management in Arid and Semi-arid Regions: Prospective and Challenges for the 21st Century, *Biosystems Engineering*. *81*, 3–34.

[7] Modarres, R. & Silva, V.P.R. (2007). Rainfall trends in arid and semi-arid regions of Iran. *Journal of Arid Environments*. *70*, 344–355.

[8] Tabari H. & Talaee, P.H. (2011). Temporal variability of precipitation over Iran: 1966-2005, *Journal of Hydrology*. *396*, 313–320.

[9] Zeleňáková, M., Alkhalaf, I., Purcz, P., Blišťan, P., Pelikán, P., Portela, M. & Silva, A. (2017). Trends of rainfall as a support for integrated water resources management in Syria. *Desalination and Water Treatment*. *86*, p. 285–296.

[10] Mann, H. B. (1945). Non-parametric tests against trend, *Econometrica*. 13, 245–259.

[11] Kendall, M.G. (1975). *Rank Correlation Measures*, London: Charles Griffin.

[12] Theil, H. (1950). A rank-invariant method of linear and polynomial regression analysis, *Nederl. Akad. Wetensch. Series A*. *53*, 386–392.

[13] Sen, P.K. (1968). Estimates of the regression coefficient based on Kendall's tau, *Journal of the American Statistical Association*. 63, 1379–1389.